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ECL-191

MY DESIGN PHILOSOPHY

by

Jack Ryan

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INTRODUCTION

My Design Philosophy is an outgrowth of an engineering case history written with Mr. Ryan's assistance on the design of an innovative isothermal coffee cup. (See ECL 190)* Mr. Ryan's thoughts on design and the design principles he uses daily are of such practicality that it was felt a separate document would be valuable. His design ideas were obtained through direct discussions and from manuscripts of his lectures to professional societies. An attempt has been made to present his ideas in much the same casual, relaxed manner in which they were given to us.

Mr. Ryan is the president of Ryan Enterprises, a Los Angeles based firm combining several diverse industries which share a common trait; they are money-makers. Ryan Enterprises seeks out novel design ideas and refines them to the point at which they can be licensed out to manufacturers for production and sales. Ryan Enterprises is thereby relieved of the manufacture of a product but receives royalties and fees from the licensee. An oil base multi-color paint, a wood veneer two thousandths of an inch thick which may be rolled like paper without cracking, and a passive coffee cup which maintains coffee in a drinkable temperature range for over thirty minutes are examples of the diversity of this firm's products.

In addition to his work with Ryan Enterprises, Mr. Ryan is also associated with the Mattel Toy Company as a Research and Design consultant.

Ryan's educational background was highlighted by four significant learning experiences. As a youth, he was informally tutored by his older brother who shared his interest in electronics. Throughout most of his secondary education, Mr. Ryan was exposed to challenging ideas, principally in science, that fed his curiosity.

During World War II, while still in his early teens, Mr. Ryan went to work for North American Phillips as an electronic technician. This early work experience proved tremendously valuable because it gave him a practical look at what he was studying in school.

The third significant learning experience was gained while attending a preparatory school. Mr. Ryan was given the

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*ECL 190, The Isothermal Cup, G. A. Sousa, T. W. Tesche, The University of California, Berkeley, California. Published by the Stanford Engineering Case Program, 1972.

leadership of a drama production which played several road engagements. The experience gained in this endeavor gave him an introduction to project management and responsibility.

Jack Ryan received his Bachelor's Degree in Electrical Engineering from Yale University in 1948 and worked for several industries before forming Ryan Enterprises and associating with Mattel Toy Company.

He holds approximately 200 U. S. patents and 800 foreign patents.

Perhaps one statement sums up his ideas on education and experience better than any personal sketch could. He has said, "The real learning experiences are the practical ones which make the academic courses meaningful."

DESIGN AND ITS FOUR STAGES

A few words about Mattel may demonstrate how important creative design has been to Mattel. In the last 17 years Mattel has experienced over 60-fold growth. Today annual sales exceed $250,000,000. It has come from a small toy company in Los Angeles to the largest toy manufacturer in the world.

About one-third of the annual sales will come from products which are carried over in the line essentially the way they were sold the year before. Another third of the toys will have to be re-designed like a new model of automobile coming out -- face lifted, up-dated -- still has 4 wheels and a motor in front, but it's a new model. And another third of the line will come from totally new concepts. The new product need is such a large percentage that it is a bit like the new product need of a larger company of around 1/2 billion to 1 billion dollar sales.

Now you may ask who does it? Who turns this out? Mattel presently has approximately 400 people in the Research and Design Department. They are quite an interesting mixture of mechanical engineers, electronic engineers, chemists, acoustics experts, fashion designers, sculptors, artists, hair stylers, writers, industrial designers, educational psychologists, and machinists. So it makes for a very interesting group at lunch; everyone does not talk the same shop. You might ask where the ideas come from? Some of the ideas come from the outside. We receive two to three thousand suggestions each year for new products from the outside. But not many of them make it into the line for a variety of reasons. About 5% of the new products may come as new

materials and processes become available. Someone will come up with a recording wire or something like that and we'll say, "That's nifty, let's try that." Another 20% of the new ideas come from the blue sky kind of thinking that one normally associates with creative people. There is a man sitting at a drafting board or at a desk, perhaps with his feet up, and you can't tell whether he is sleeping or being creative. Suddenly a light bulb lights above his head and he has a brilliant idea. He has invented a solution and then you are faced with a difficult job -- finding the right problem for that solution. That is the hard part when it comes to spontaneous creativity. About 70% of our ideas and patents are based upon invention to order. While this is a little harder to do, the yield is much greater. If you just throw your seed on top of the ground some of it will grow; if you really dig and plant it, it will grow much better. So we try to find out what is needed and concentrate on trying to invent something that fulfills a need -- we try to be creative about imagining what would be wonderful if it happened.

We have a rule of thumb that may illuminate the nature of the design process. This is, that 80% of the effect is created by 20% of the effort, and the remaining 20% of the effect is created by 80% of the effort. In other words, the main part of the job - the first 80% - gets done with 20% of the effort. We take very good advantage of that leverage. We put a lot of emphasis on doing things 80% of the way and then seeing if we really should have done them. You can see the reason for this by considering our four stages of design:

1. Feasibility design - Does the raw idea work?
2. Preliminary design - Can the raw idea be made into a product?
3. Product design - What is the complete configuration of this product?
4. Manufacturing design - How can this product be manufactured at a reasonable cost?

We are super-critical of spending the remaining 80% of the time, putting that 20% of the polish on an idea unless it withstands all kinds of rigorous tests and examinations. We are ruthless with the ideas once they have grown to that 80% point and we just create more of them; if that one does not work, there are 10 more where that came from. And that is how we keep turning them out. But we don't invest the remaining 80% of the effort which is the expensive and time consuming part unless the thing really passes every test. One thing we try to do is provide a constant interaction between the research people, the marketing people, the management people of the company and the consumer. The consumer

in our case is both the parent and the child. But this constant interaction at an early stage of design keeps us calibrated, keeps us tuned to what is really wanted. If we just sat and designed for ourselves as some designers do, we would again be faced with the task of trying to find a problem for the solution we would come up with.

I am not really a teacher of creativity at all. As a matter of fact, I became a student of the process of creativity when I was asked to express my ideas and it started me thinking about it. It reminds me of the story about the centipede who was asked how he walked. He began to concentrate on which leg he put forth first and became paralyzed because he couldn't do it. It is largely an autonomous sub-conscious process. So it is hard for an inventor or someone like that to tell you exactly how he goes about doing it. But I will try to tell you something about the environment that we try to provide and some very practical short cuts that have worked for us.

The first thing is to define creativity. You could subdivide it into at least two aspects. One of the major ones is invention. Everybody knows about that and it has been glorified. The other is the one that is often neglected -- discovery. Discovery is the much more common but unglamorous action of stumbling across something.

In the missile business many people make random discoveries, and then run to their mathematician friends to have them turn out all the equations to explain why they invented it. In fact, they just overlooked something. We have to remember that what we are trying to achieve is an artistic result. What we are really trying to do is satisfy a person, just as an artist does. You are trying to satisfy a consumer with a product and that is essentially an art. Those of us in the product field practice this art through the use of science, so we achieve this purely artistic effect. We are not trying to make a device, we are trying to satisfy a person. It is important to remember that. We use all these scientific tools to achieve that artistic result. But we must not get confused and think we are trying to produce a mechanical end result. We are trying to produce an effect, which is satisfying to the consumer. We are not trying to produce hardware. The hardware is just how we do it. The technology is how we produce the hardware. Now it gets back into a circle as many things in life do. We achieve this artistic effect through a scientific approach, but the scientific aspects of it go right back to being an art. So creativity is not a science - i.e., science is a prerequisite in many fields of creativity but the creativity is itself an art.

In order to have a creative environment it is necessary to keep an atmosphere of enthusiasm. The enthusiasm cuts both ways. We need enthusiasm on the part of the designer and we need enthusiasm on the part of management of the company representing marketing and the consumer. Their judgment of marketing and the consumer is important. So the designer must be enthusiastic and then management's enthusiasm must cheer the designer on to greater achievements. If he runs into a design problem half way through something and management has been discouraging him anyway, he is not going to find the answer. But if they have been cheering him on and telling him how great it is going to be when he finally gets it, he will find a way. Now as a research director you present the designer's design to management in such a way that they will appreciate it and be enthusiastic. You then interpret management's comments about the product so that the designer will feel enthusiastic and not be pressed by some of their occasional criticism. The important thing in creating is to create something that happens -- something that will be used and appreciated. Creating for the sake of creating may be a satisfaction to some but it is short lived -- if it can not sustain itself the company will not sustain it.

I think of the story of the tree falling in the woods and the argument over whether the tree creates a sound if it falls and no one hears it. That is an old thing you may have heard. They used to debate it years ago. I don't know whether it makes a sound or not but who cares? If you design something and it does not happen, that is not much fun and it doesn't make money or do any good.

ECONOMICS KILLS MOST DESIGNS

The thing that kills most projects, at least most of the time, is the economics of design. People set out to design something and when they are all through, it just doesn't work out. The whole economic philosophy of design is that you don't end up designing something that is in the wrong economic walk and won't happen. This is something that designers don't think about. They are usually thinking about designing what they are designing. After you see 80% of what you do successfully yourself fail for some other reason you begin to think, "Am I spilling my blood on the floor for nothing?"

If you design just to replace an existing product, it doesn't attract dollars to trade for the money you are investing to do it. So it is important to design something that is new and different, but not so different that the marketing people can't really visualize it or set an accurate sales quota on it. When you come right down to it, it is necessary to

estimate the economic pay-off of the thing. If you give them something that is similar to, but better than, something that they are familiar with, they can predict a quota within an accuracy of probably 20%. If you give them some way-out thing like a Sky Cycle that a kid can pedal around the neighborhood just over the roof tops, they don't know what to do with it. They couldn't estimate the quota within two orders of magnitude. Will the parents let the kids fly it? Do you need a license? and all that sort of thing. So you can't get too far out.

In steering people away from pitfalls that might lead to discouragement and dampen enthusiasm leading to creativity, it is important to remember the realities of life. Long before the product is ever conceived, perhaps when the marketing people expressed the desire for a new $3.00 something-or-other, it is important to predict what the cost will be. The engineer may think, well, first I'll design it and then I'll know more accurately what it consists of and then I'll do a cost estimate. It is better to work backwards and to set a budget. Say they want this thing for $3.00. We know they are going to put it in a box and a $3.00 product comes in a box about this size, so you know that is gone from your budget. And it is going to have some plating on it and some painting on it because for $3.00 you just can't give them a piece of plastic un-decorated. So you go through and hypothesize and bracket out a budget and after you've done that you go right back to them and say, "there's no way". So don't let us waste four months trying to create this thing for you -- let's re-define it. You either need fewer features or a higher selling price. Or let us come back and see if we are lucky and maybe we can give you something marvelous for $5.00. They may say $5.00 is not a supportable price in that market, in which case you go on to the next product. And then through the course of design it is necessary to constantly re-guess the price. It is all a process of guessing. You don't have to know too much to guess because by the time you know you've got too much into it -- then it is too late and you are already committed to a direction.

I'll cite an example of how it can go first one way and then another way. Suppose the head of marketing says what we need is a $1.50 cap pistol. And what they can do is say, that's going to have to be pretty economical, as economical as it possibly can be. And so the designers come up with a design in which the hammer and the trigger are all one piece, sheet metal, and the hammer spring also functions as the trigger spring, and the end of the spring advances the caps. And you say, that is the absolute bare-gut, simplest cap gun I think has ever been designed and made, and we have a model here. But well, they are not sure, it doesn't fire too

reliably. So you re-engineer the thing and you get it so that it really fires reliably.

Now you make an appearance design, having proven the feasibility of the simplest possible mechanism. Then send some preliminary drawings out for quotation and then you figure out a cost estimate on the thing, and then you see if it can sell for a dollar fifty.

Another way of doing it is to say, Okay, you want this gun to sell for a dollar fifty. How small may I make it? The fellow says, I don't know. Can't be too small. You say, Well, I don't want you to tell me what's all right, but would that be too small? And the fellow says, Oh, yeah, I mean it couldn't be that small. So you say, Okay, now could it be this small? The fellow says, Well, maybe. So you say, well it has got to be at least this big, and he'll say, yeah, I would like to see it a little bigger than that. So you say, Okay, it has got to be at least this big. Fine, now that means you are going to want a box, right? They wouldn't want to put it in a box cheaper than some other product you may name that's in the line. Oh, no, you must have a box. Oh well, we are going to be stuck for price, so what's the cheapest thing you could think of putting this thing into? A plain tuck-in, chip box is about as cheap as you can get. So you say, Well, there's seven cents cost right there, plus the labor of putting the gun into it, so that's eight cents.

So you say, what are you talking about? You don't even have the gun designed. Fine, you go through the whole reasoning process and maybe you end up finding that you can't afford to chromium plate the gun or even nickel plate it, and all you can do is put on a bright zinc plate and a little lacquer over it. So then you go and show them a nice shiny zinc plated gun and you say, Is this appearance okay? And the fellow looks at it and says, Yeah, but it looks a little funny. You say, Well, after a month of use it is not going to look like this. It is going to get dark because we can't afford to nickel plate. It costs about nine cents to just nickel plate the two halves of a gun this size. Without knowing what the design of it is, it is still going to cost that much. And you say, That leaves me two cents for the whole mechanism, so assuming that I can be ingenious enough to invent a mechanism that will work for two cents we can just skin through with this product and you don't like it too well because it is a litte bit on the small side and it has this cheap plating on it. And by the way we haven't invented a mechanism that will do the job for two cents. However, if we did, and let's assume that we did, how many can we sell?

Because of the low selling price and the margin on the thing, the amount for advertising will be small. Specifically, the fixed costs would be somewhere in the vicinity of forty per cent of the total cost, so out of a dollar fifty selling price you would assume that you had forty per cent of that, or sixty cents to amortize all of the various fixed costs that go into the thing. So you begin talking to them and say, I suppose you are going to have to advertise this, and they say Oh yeah, we'll have to put them on television or otherwise you would never notice it from any other gun on the counter. There are so many cap guns, you will have to point out the unique features of this one. So you say, Well, what is the minimum cost of advertising? And they say, We've got to spend a hundred thousand and more likely a hundred and fifty thousand. So you say, Okay, I got sixty cents there, if I take fifty cents of that for advertising, that's like ten per cent, and I want to get one hundred and fifty thousand dollars, at fifteen cents each, how many do I have to sell? You have to sell a million. Well, you'd go through the line and you'd say, Think you could sell a million? Well, I might sell a million, but I think I'd have to go heavier on the television to push. I could get half a million across the counter, but if you wanted to sell a million of those things, you really would have to give it a pretty strong push on television, and have something worth advertising. You know, you can just say, Ours is better, buy ours, but you can't build a reputation on that kind of stuff. You say, Now assuming you guys come up with something really great (for two cents) then we go up to two hundred thousand dollars for advertising. Then we would say, Well, in order to keep the price down, we are going to have to shoot these guns, four of them, in a great big die casting machine. We can't make them one at a time; you've got to make them four at a time in the big machine. And the tooling for that is going to run us around a hundred and twenty-five thousand dollars, something like that. So that's another big expense. They have a hundred and fifty thousand dollars for advertising and one hundred and twenty-five thousand dollars for tooling and then it is going to cost us another fifty thousand dollars for engineering it and then there is another fifty thousand dollars associated with overhead and all that sort of thing. It ends up probably that you are going to have to sell a million, two hundred fifty thousand of these marginally small items, in a cheap box, with a crummy finish, that you haven't bothered to design as yet.

Now I'm saying you can do all this quite quickly. You should always have a cost estimate running simultaneously with the project and consider the fixed costs associated with the project as well as the variable costs. The fixed costs can be very large. And we do that quite often. They

will come to us and say, Can you design a movie projector for kids? We say, What's for kids? Well, something that will sell for around thirty dollars. Well what is the discount structure on something that sells for thirty dollars? Do we have to get it out of here for fifteen dollars or could we get it out at nineteen and still have them retail it at thirty? And, we'll say, We are in the low price market, no discounting; you could probably sell it out of here at nineteen dollars and they'll get it on the market at thirty. But that's the limit. Okay, and you just work from there and say, Well, let's see, it is going to have to have a lamp and a motor, and a line cord and a plug and a box and you get into all of those things and see how much you have left for the things you haven't designed yet. And you can probably tool it down to size very quickly. You pick a competitive projector and say, Now where is this going to be better than his, but let's see what expenses they have. Ours will be more ingenious and it will have fewer parts, and it will perform better and all that marvelous stuff, but there are certain knowns, and instead of having to guess at a whole big unknown, you find that it is very easy to whittle away two-thirds of the unknowns. Now when you are guessing the remaining third you can guess more, and then your total guess is much more accurate than trying to guess the whole thing. There are many things you don't have to guess. So you whittle through this design very quickly and figure out which things you don't have to guess, things that you can get a quick fix on and you don't care to stop with that as a design you're after. See what I mean? It's just a test of reasonableness of the whole thing.

Lots of design requests are unreasonable. What this country needs is a good 5¢ cigar. You know somebody always comes up with a system that these days you have to package in such a fancy way that the package costs 4¢ and you wouldn't want to smoke a 1¢ cigar.

YOU CAN CONSCIOUSLY STIMULATE YOUR CREATIVITY

The process of creativity and invention is not well understood and cannot be learned as a skill such as riding a bicycle or serving a tennis ball. Nevertheless, there are things to do and things to watch out for which can improve your creativity. The following are some points which seem significant to me.

Intuition can be useful. I have found that most of the time that gets wasted on projects is due to the limitations that are put on people's thinking or by considering the right things at the wrong time. Someone will be working in a very preliminary stage of design and naturally you have to have

then an intuitive feeling that what you are doing is practical. A boy who puts a 2 x 4 across a stream and then walks across it doesn't know anything about civil engineering but he knows that his 2 x 4 will hold him up as he walks across the stream. He just has an intuitive knowledge of the behavior of material and he doesn't calculate anything. He just puts the 2 x 4 down and walks across. What you have to do is calibrate yourself to do these things intuitively in the early stages of design and to explore the boundaries of your solution. How much is too much? How little is too little? What is the range of solution? Consider alternatives which range to the absurd.

When we do the feasibility design, we just see how it works. If it shows that the principle works, then we go on from there. But there might be lots of reasons why a feasibility design might be impractical. It might be too heavy, too expensive, or too ugly. So we don't cost out this design any more than the hundreds that we wanted to avoid. To consider these things but not be bogged down in them is the technique. Don't stop and make a market research model of a feasibility to see how people like the feel of it. You know, there are all kinds of types. The market research people would have four different designs to try -- one that weighs two pounds and one that weighs one pound and so forth. But you just do those things intuitively. And the sharper your intuition is the better the solution you will come to.

Now I was just mentioning sharpening your intuition, and getting yourself calibrated. Suppose you are trying to design something for minimum weight or mimimum cost and you don't know whether or not you are going to have to put stiffening rims in the side walls in order to hold this thing together. Or let's say that you've got a tube sticking up to support a mirror on a truck or something. Now, suppose you go up to the next gage of material. How much stiffer will the structure become? The strength is a function of the radius cubed so a 10% increase in diameter yields a very big payoff. Some people won't think of thickening the wall or something. They will say, Well, gee, we are making this out of plastic and it is just flimsy, without realizing that a slight increase in diameter would remove the need for a more expensive material. You have to know when you're ahead, where the easy payoffs are. Getting the easy payoff in this case with increased diameter would yield another payoff. The machine time will decrease because the injection molding machine will fill faster. If it fills faster you'll trade off machine time against material and you'll come out really with a better part. So I'm just saying you can't calculate all those things, but the more things you have an intuitive feel for, the faster your design will go.

Invention and analysis are often glamorized. The one thing that's usually neglected is discovery. Discovery is the much more common but unglamorous thing of stumbling across something. I think many of us stumble across things and then intuition is to have an educated toe, and realize you have stumbled across something and take advantage of it. It would not hurt also to be less hypocritical about it and try not to rationalize it as an invention rather than a discovery. There is no shame in discovery, as your intuition made it possible.

Choose the proper medium for the stage of your work. The medium in which you work influences the state of your thinking. Therefore, it is extremely important that the medium in which you work is appropriate to the project's progress. I've found it very necessary to separate design into categories and to insist that people not gravitate to the next higher medium of design prematurely. Again our four stages of design begin with feasibility design -- does the raw idea work? Second is preliminary design -- can the raw idea be made into a product? Then we have product design, which is where the product is really created, where you figure out exactly what it's going to look like and exactly what its features will be and cost. Finally, there is a long laborious task of manufacturing design, where you all go over draft angles, shutoffs and inserts and that sort of thing. This takes most of the work and contributes the least unless you do it wrong. Then you're in big trouble. If everything is done right there's no credit in doing it, except that you didn't screw up.

There is a tendency for guys to get too far into the design and begin considering too much too early. But you must consider the practicality. Now it sounds like I am telling you two opposing things. I'm saying don't worry about the later stages of design, and yet I am saying worry about them, even worry about the economics. But just do it, try to do everything like a kid with a 2 x 4 as a bridge to cross a creek. Estimate and use your intuition. But just because you can't invesitgate everything, don't freeze something. There is a tendency on the part of many people to say, Gee, I have nothing, nothing is fixed. Well, let's freeze this, and then we can go from there. Well, why freeze that? Maybe that's not the thing to freeze or the place to freeze it. But if you get into this psychology of designers and engineers, you see that lots of them aren't at home unless they have a firm plan from which to work. And if they are comfortable we tend to let them start that way, but also make them realize that the plan can be changed later on.

Mistakes should be made! Failure is not fatal. Many people feel that to fail is to die somehow. You've got at all costs to assure against failure. In an atmosphere of preliminary design it's important not only to tolerate but to encourage a certain failure index. If people are not making a few mistakes, then they are working much too conservatively. You are not cutting steel spools, you are working with a rubber eraser, or better than that, a clay model. Too much failure, of course, won't be tolerated in any situation, but it's important to remember the other side of it. Don't tolerate too little failure in a preliminary effort.

There's a kind of designer who loves to do everything perfectly. He's the guy who starts out with a 4-H pencil and has everything drawn so you couldn't erase it if you had to. When he sends his work to the shop to be built it comes back and it works. Now, that's overdoing it. In order to have that degree of accuracy, the guy isn't making enough mistakes. If a guy isn't making enough mistakes, he's not being ambitious enough and he's not working quickly enough. You have to have a certain rate of failure. Nobody is that perfect. So the guy who tries hard and never makes a mistake is limiting himself. One should work more like an artist with some charcoal. I'm saying engineers can learn a lot from artists. You just kind of scribble it out there and you don't care because you can just wipe it off. The looser you can work, the better off you are.

A common mistake made by designers is to never go far enough; there's a conservatism in many engineers; they like to be sure of themselves -- to be sure of what they are doing -- and so there is a conservatism that says, Well, we put this much something or other in and this works and they are satisfied with that. What I try to encourage them to do is to explore the boundaries, find out where the boundaries are and try to come up with some kind of a mental picture of the parameters involved. It isn't always easy to express it graphically or mathematically but when you are working on something like tuning a radio set or television set, you set the knob and you get a picture. Will you just sit there with that picture? No. You tune past it until you have gone too far one way and you tune back until you have gone too far the other way and you have seen what both of those limits look like and then you are ready to know that you have the best picture you can get, somewhere in the middle. You know it may contain a lot of snow and distortion; at least you don't just snap the set on and say, Oh well, look at that picture or turn the knob to that point and then stop. So it is important in any design to explore how much is too much, how little is too little on each of the parameters of the thing but not to waste a lot of time doing it.

Often it is advantageous to collect a box of tools and spare parts. I have a whole set of tools in my desk drawer. A lump of clay can help you see what things look like. It's also good to collect an assortment of ingenious little doo-dads. Many devices contain clever little mechanisms and if you have the advantage of a junk box, not of just nuts and bolts but of things, something may catch your eye, trigger your imagination and presto - an idea! They won't fit your machine but it serves as a mental scaffold because you can put something together and get it bouncing on a rubber band and see how it tends to rotate as it bounces or something like that.

Along the same line, it is helpful to maintain a file cabinet of catalogs, ideas, technical articles and the like. While a designer cannot possibly hope to read and remember all of the material that crosses his desk during the year, if he files it away in some logical manner, at least he has this information at his fingertips. In a sense, it's like adding extra storage capacity to your mind.

A mental scaffold should be built. Basically, it's an artificial method which allows you to see past the first design hurdle. Here's how it works. When you're building a building it's hard to work on everything at once. You might think you'll build the ground floor and then you'll build the second floor and then you'll go to the third floor. Many designs are done that way, but the right thing to do is to instantly erect a mental scaffold in a form of a mock-up of the product to help you visualize and see the whole thing in rough form.

Practically speaking, this may be done by quickly fabricating the first stages of the design using things like wire, clay, string and tape, and progressing to the next stage for a glimpse of problems to be encountered and factors which might alter the works of the design. You can then, if you build yourself a scaffold, climb up on that scaffold even though it's a temporary thing and see further. You can see the next story of the design.

Simulation is very important. Someone may say that they want a product, for example, a coffee cup that would do a certain thing and have certain characteristics. Sometimes the best thing in the world to do with the marketing people is simulate because you'll either be doing the marketing yourself or more likely working with marketing people whether they are trying to sell an SST or a coffee cup. Simulate the thing for them and let them realize that this is a simulation. You want their cooperation here, realizing that this is a simulation.

For instance, we made an audio-visual device. We have some people who thought that an audio-visual thing that would do this, that, and the next thing would be just marvelous. Instead of engineering the whole product and then showing it to them, we simulated it. We made a mock-up of what this device would look like and sat it on a big table. Actually, there was a cloth over the table and underneath the table was a very expensive projector and a very expensive tape recorder. Instead of the operation of the device being done through some logic associated with the buttons that these people press, we just had somebody watching through a one-way mirror and you would give the correct response by switching to the appropriate image and saying the appropriate thing on the microphone. Had we gone ahead and developed that whole thing they would have then decided that they wanted it quite different, so simulation is very important.

Try to think of ways to pretend that you're there for a minute. Now what if I did have that, then what would I do? The next thing I do is change it. As soon as you bring the Model T in to Henry Ford, he starts thinking about the Model A, right? He just finished the Model A and the Model T is already down in price and he has some idea for a V-8. Management always wants to know, Why all this fooling around? Why didn't you build a Thunderbird? We're talking about simulation and talking about pretending you're at the end result which is important.

You can even do that with experiment. I was in the missile field for awhile and I authorized experiments to be done by other laboratories, when my people were busy. I wanted a certain test run, an environmental test or something like that. It's a very good exercise and a very good discipline to yourself when you're doing the experiments to sit down with somebody who is new and say, Let's pretend we just got the results back from this. Let's just fake out a data sheet here, now what are you going to do with this result. Lots of experiments either are not completely necessary or don't properly explore the boundaries. Someone may say check this at this voltage, and this temperature, etc. Maybe that's not the way to define it. Maybe you don't want to do that. You say, run one up until it blows out and run one down until it stops working and then we'll see where to go from there instead of trying to define beforehand a whole testing program. The technicians might not care. Plug another one in. Yeah, that one blew out, plug in another one. It runs into a lot of money and time and you get back a data sheet that shows that something was wrong. It won't stand that much voltage. Imagine if you have the results of what it is you're trying to do and then what would you do with them and you'll save yourself a lot of time.

If marketing asks for a product, one of the most effective techniques is to simulate that product and to bring it back to them as though you have designed it. And just say, This is the way it works, now this isn't the final mechanism, but this is the way it works. And you show them an exterior that looks just like what they asked for and it functions like what they asked for. They're confronted with a decision. If they can put you on -- people procrastinate. Even marketing people procrastinate, and you can force them if you confront them with what the experts say. Now what are you going to do with this? It's interesting. Suddenly they ask for the Mark II version. Now you would have been a darn fool to go ahead and design the Mark I which they asked for.

Simulation is very, very important. People consider it cheating or misrepresentation, but that's not the case. As a matter of fact, we have on our staff two magicians and we have often employed them in the demonstration of a product that wouldn't work properly otherwise. They'll walk up to the marketing people, and they'll demonstrate the thing and they'll see it works and that's the ultimate in simulation.

If the magicians can't pull us through we have another trick, and that is to make a movie of the device, a demonstration film. Nothing worries management more or turns off the marketing people more than having a model that you bring in and then it doesn't work and then you run and get a fuse and fix it. That really turns them off. Timing is everything. So when you're making a product presentation with something that's risky, one of the most effective techniques is to make a movie of it. Edit the movie down and if the darn thing doesn't move you tie a black thread on and pull it so that it does move. Now that's simulation again, but it gets the idea across. As soon as they look at it they're going to say, Well what's that . . . it moves that way . . . that's not what we thought of. To which you reply, That's what you asked for, now what <u>do</u> you want?

<u>Messy work</u> can yield good results. Another useful point that too often designers forget to consider is simply this -- for best results keep your work messy during the preliminary stages. We try to keep in the preliminary design phase things in clay and scotch tape and mechanized other products that get glued together with the original ones. It's very important to have a model be such a mess that there's absolutely no harm in chopping it up and changing it. As soon as the model becomes beautiful and the designer is in love with it and he would rather have you cut off his child's arm than cut off the doll's arm, he becomes too involved with it and it becomes too finished. I urge people not to do too good a job too early. This does not condone laziness; rather it recognizes that at the beginning of a design the designer must

remain flexible and unencumbered by preconceived notions.

The other thing is, don't resist changing your mind. It's no crime to change your mind; that's what you're supposed to be doing, evolving something. Again we are taught that it's kind of a weakness to change your mind; not so in preliminary design. Encourage mind-changing.

People think linearly; they just think that way automatically. Calibrate your intuition, particularly looking for things that are not linear; nonlinearities are tricky, misleading, and they also can be very useful where you have discontinuities in the function of things.

As a matter of fact, in business you can often outsmart competition by looking at a business situation and finding the nonlinearities in the intricate pieces of a business situation. Assume that the guy that's running the business is an intuitive kind of a guy or he wouldn't have been able to get there in the first place, but he may rely too much on his intuition and not know the discontinuities in the business. For instance, in production some salespeople will assume that if they can sell more they'll make more money. The first element of sophistication is to realize that when you get a quotation from a manufacturer he says, Well, if you order a thousand it will cost you 10 bucks apiece but if you order 10,000 it will only cost you 9 bucks apiece and if you order 100,000 it will cost you just so many dollars apiece. We went through this with every one of our vendors. As time went on they would not give us a formula but they would give me some quotations and I found that by just plotting his quotation I could learn a lot. Some people had a pretty good idea of what your business was like. It came down to some kind of a fixed cost for handling and ordering, like $100 just to talk to you and set up the machine; they set up a screw machine and from then on there would be variable unit price and a fixed cost. You should always look for that when you are figuring out the price of something. There's a lot of money involved and then beyond that there's an incremental cost. You can get into such a high volume that you automate the thing and you'll have another big step in the fixed cost of doing it and then you know the cost will become even less.

When you are stumped, change something. It is important not to be afraid to change. It's just sketches in charcoal. If you look at some of the works of the old masters and their preliminary sketches, the preliminary sketches often have different arrangements of figures, changes in perspective and that sort of thing. After they said it in charcoal they changed the set-up completely. And we shouldn't be afraid to do that either. As a matter of fact, it should be encouraged.

I'd say that the key to the whole thing is rapid successive overall evolution. You've got to move quickly. You've got to do it successively many times and know that you're coming back so you don't have to perfect it the first time. Evolution is the key word. You can't concentrate on one aspect of the project; you have to do it over-all, constantly evolving.

At the outset of some projects many a designer has said, I'm stuck, completely stuck. He couldn't get started. A normally creative mind has just seemed to go blank. To give a boost at these times I've seen design supervisors say, Well, just draw a line. Put it right there in the middle of your paper. That's your start, now change it. The designers came to realize that they could do a lot more than they thought. They just had to stay loose, not worry about mistakes and be ready to make changes.

Orthogonal design is limiting. It used to be that things were built by people and the same man who had the idea made the thing. So he wasn't working from drawings. Then, it got to the point where there were people who worked with their hands, and those who worked with their minds, and those who worked with their minds but expressed it on paper. That's as far as that went and they became the designers who designed things. They thought about something and expressed it on paper and then others built the things.

Orthographic drawing has shaped the world and has shaped products an awful lot. Most things are designed so that they can be drawn in plane view and simple elevations. That's very very limiting in design. It's really hard to do a good design that way.

When we were putting stuff inside of a missile, we had the job of fitting everything in. One of my jobs was fitting everything into the Hawk missile which is a low altitude defensive missile. You could get a lot more in using clay and the actual part than you could on paper because the surfaces were all curved. It's a cylindrical missile. So how do you start making a layout of all the hardware. There were fellows who'd make drawings, a flat drawing of one-third that was tilted correctly in the view and everything. What is that for? You know, that doesn't do anything. It would work much better by just curving up a board and actually sneaking in the parts. And you say, I could put this part in diagonally or crosswise. You don't see those things on paper as quickly. If you have the parts right there, or if you have little blocks of wood that represent the parts you can see that, sure it won't go in this way and it won't fit that way, it won't even fit diagonally. But if you lift this end up and tip it a little bit, it will fit.

So, I am an advocate of three-dimensional design. For example, try to improve the contour of the things on a zipper. That is certainly three-dimensional design. You don't lay out a zipper on paper and make those teeth fit together.

In conclusion, it seems evident that design is neither simple and straightforward nor mystical. It is a combination of many factors. Design is art. Design is science. And design is highly personal. Thus, my thoughts are useful for me and may be useful for you if they can be integrated into a personal approach which works for you.